

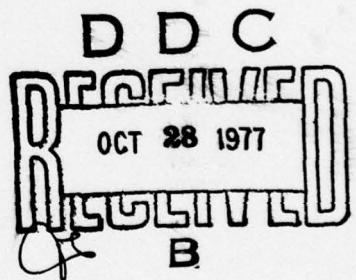
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PROSPECT THEORY: AN ANALYSIS OF DECISION MAKING UNDER RISK

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Daniel Kahneman
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ADVANCED DECISION TECHNOLOGY PROGRAM

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TECHNICAL REPORT PTR-1042-77-4

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by

Daniel Kahneman and Amos Tversky

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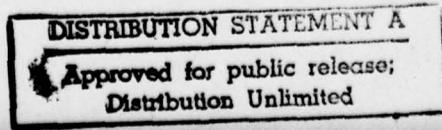
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April 1977

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SUMMARY

The application of scientific methods and formal analysis to problems of decision making originated during World War II from the need to solve strategic and tactical problems in situations where experience was either costly or impossible to acquire. It was first labeled "operation analysis" and later became known as "operations research".

Operations research provides sophisticated modeling of decision situations but lacks an effective normative framework for dealing with uncertainty or with the subjectivity of decision makers' values and expectations. Over the years, such a normative framework has been developing under the label "decision theory". The objective of decision theory is to provide a rationale for making wise decisions under conditions of risk and uncertainty. It is concerned with prescribing the course of action that will conform most fully to the decision maker's own goals, expectations, and values.

Present-day technology for making decisions, commonly known as decision analysis, represents a blending of the modeling techniques from operations research with decision theory. Thus the usefulness of decision analysis depends upon the validity of its underlying theoretical rationale.

This theoretical rationale is continually evolving. To date utility theory has served as the guideline for wise behavior. However, the present paper shows that utility theory is not adequate to describe how people want to behave. This descriptive inadequacy has implications for the normative validity of the theory and for the practice of decision

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analysis. An alternative theoretical formulation, called "prospect theory", is presented here.

Prospect theory arises from the observation that people's choices deviate from utility theory in two important ways. One is the tendency for people to isolate a choice problem from their assets and evaluate it in terms of gains and losses. The second is the replacement of subjective possibilities by uncertainty weights which reflect attitudes toward uncertainty and not merely degrees of belief. These findings invalidate the attempt to infer utilities and subjective probabilities from preferences. No consistent utility function for wealth can be inferred from the choices of people who evaluate gains and losses in the ways observed here. Similarly, one cannot recover a proper subjective probability measure from the preferences of a subject who applies uncertainty weights.

The observation that people's preferences depend on the formulation of problems underscores the need for decision aids to help people make more consistent and rational choices. At the same time, these observations suggest ways to improve the procedures currently used in decision analysis to elicit utilities and probabilities.

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ACKNOWLEDGMENT

Partial support for this research was provided by the Advanced Research Projects Agency of the Department of Defense and was monitored by the Office of Naval Research under Contract N00014-76-C-0074 under subcontract from Decisions and Designs, Inc.

I would like to thank Nancy Collins, Michael Enbar, Sarah Lichtenstein, Paul Reiter, Peggy Roecker, Paul Slovic and Mark Weinrott for varying combinations of discussing issues raised here, commenting on previous drafts and typing.

1. INTRODUCTION

The idea that people maximize expected utility has dominated the analysis of risky choices. Expected utility theory was formulated three centuries ago by Daniel Bernoulli (1738). It was first axiomatized by von Neumann and Morgenstern (1944) and then generalized by Savage (1954), who integrated the notions of subjective probability and expected utility. The theory has been applied as a descriptive theory in economics, to explain phenomena such as the purchase of insurance policies and lottery tickets (Friedman and Savage, 1948) and the relation between spending and saving (see Arrow, 1971). It has been applied as a normative theory in decision analysis to determine optimal decisions and policies (see, e.g., Keeney and Raiffa, 1976). Indeed, most students of the field regard the axioms of utility theory as canons of rational behavior in the face of uncertainty, and they also regard them as a reasonable approximation to observed economic behavior. Thus, it is assumed that all reasonable people would wish to obey the axioms, and that most people actually do, most of the time.

The present paper shows that actual decisions under conditions of uncertainty do not obey the axioms of utility theory. Furthermore, the observed violations are common, large, and lawful, hence they cannot be treated as random error. Consequently, we argue that utility theory, as it is commonly interpreted and applied is not an adequate descriptive theory, and we propose an alternative account of individual choice under risk.

Decision making under uncertainty can be viewed as a choice between gambles or prospects. For simplicity, we restrict the discussion to two-outcome gambles with (so called) objective probabilities, although most of our conclusions are not limited to such gambles. Let (x, p, y) denote a prospect where one receives outcome x with probability p and outcome y with probability $1-p$. The prospect of receiving x with certainty is denoted by (x) .

The application of expected utility theory to choices between prospects is based on the following three tenets:

(i) Expectation: $U(x, p, y) = pu(x) + (1-p)u(y)$.

That is, the overall utility of a prospect denoted by U equals the expected utility of its outcomes.

(ii) Asset Position: (x, p, y) is acceptable at asset position w if and only if $U(w+x, p, w+y) > u(w)$.

That is, the prospect (x, p, y) is acceptable if the utility resulting from adding that prospect to one's assets exceeds the utility of those assets alone. Thus, the domain of the utility function u is final consequences (which includes one's asset position) rather than gains or losses.

Although the domain of the utility function is not limited to any particular attribute, most applications of the theory have been concerned with monetary outcomes. Furthermore, most economic applications introduce the following additional assumption:

(iii) Risk Aversion: u is concave ($u'' < 0$).

A person is risk averse if he prefers the certain prospect (x) over any prospect with expected value x . Clearly, risk aversion is equivalent to the concavity of the utility function. The presence of risk aversion is perhaps the best known generalization regarding risky choices. For example, most people prefer 450 for sure over the gamble $(1000, 1/2, 0)$ although its expected actuarial value is 500. Similarly, most people are not willing to accept the gamble $(1001, 1/2, -1000)$ although its expected value is positive. Indeed the presence of risk aversion led the early decision theorists of the 18th century to propose that utility is a concave function of money. In the modern (axiomatic) approach to utility theory, the concavity of the utility function is derived rather than postulated [see Pratt (1964), and Arrow (1971)]. According to expected utility theory, therefore, risk aversion is accounted for in terms of the utility function for money, with no reference to risk per se.

We argue that these three tenets of utility theory are incorrect as a description of individual choice behavior. We first demonstrate several phenomena which violate all the above tenets of expected utility theory, and then we introduce an alternative theory for decision making under risk.

These demonstrations are based on the responses of over 200 graduate students and University faculty members to several hypothetical choice problems that were presented to them in different orders. The reliance on hypothetical choices raises the obvious questions regarding both the validity of the method and the generalizability of the results. We are keenly aware of these problems. However, all other

methods that were used to test utility theory also suffer from severe drawbacks. Real choices can be investigated either in the field, by naturalistic or statistical observations of economic behavior, or in the laboratory. Field studies can only provide for rather crude tests of qualitative predictions, because probabilities and utilities cannot be adequately measured in such contexts. Laboratory experiments have been designed to obtain precise measures of utility and probability from actual choices, but these experiments typically involve contrived gambles for small stakes, and a large number of repetitions of very similar problems. Consequently, the results tend to reflect extraneous factors which depend on display and mode of presentation. Indeed, very few consistent findings have emerged from the experiments designed to shed light on the descriptive adequacy of utility theory.

By default, the method of hypothetical questions emerges as the simplest procedure by which a large number of theoretical questions can be investigated. The use of the method relies on the assumption that people have some idea of how they would behave in actual situations of choice, and on the further assumption that the subjects have no special reason to disguise their true preferences. Thus, if people are reasonably accurate in predicting their choices, then the presence of common and systematic violations of expected utility theory in hypothetical problems provides presumptive evidence against that theory.

A comprehensive evaluation of the descriptive adequacy of a choice theory should, of course, take into account all available sources of data including laboratory experiments, field studies of economic behavior, and responses to

hypothetical problems. The relation between people's responses to hypothetical questions and their actual choices is an important empirical problem that deserves careful investigation. Note, however, that the applications of decision analysis to real problems also rely on hypothetical questions to measure the probabilities and utilities of outcomes.

1.1 Certainty, Probability and Possibility

Consider the choices between the following prospects:

$$A = (750) \quad \text{vs.} \quad (850, 0.95, 0) = B$$

Set 1

$$C = (750, 0.55, 0) \quad \text{vs.} \quad (850, 0.50, 0) = D$$

The outcomes are expressed in Israeli pounds; one pound is worth about 12¢. The majority of respondents who were presented with these choices selected A in the first problem and D in the second.

This prevalent pattern of preferences, however, is incompatible with expected utility theory. To demonstrate, set $u(0) = 0$ and note that the former preference implies $u(750) > .95u(850)$ or $u(750)/u(850) > .95$, whereas the latter preference implies $.50u(850) > .55u(750)$ or $u(750)/u(850) < .91$, a contradiction. Apparently, changing the probability of winning from .95 to 1.0 has a greater impact than the change from .50 to .55. This type of violation of expected utility theory, which arises in comparisons in which the same outcome (e.g., 750) appears in both risky and riskless prospects, is called the certainty effect.

In the above problems, the probability difference between the prospects was held constant. The certainty effect can also be obtained by fixing the probability ratio as in the following problems.

Set 2 $A = (750)$ vs. $(1000, 0.80, 0) = B$
 $C = (750, 0.25, 0)$ vs. $(1000, 0.20, 0) = D$

Here, again, the majority of subjects chose A in the first problem and D in the second contrary to expected utility theory. To demonstrate, set $u(0) = 0$, and note that the former choice implies $u(750)/u(1000) > 4/5$, whereas the latter choice implies the reverse inequality. In fact, C and D are obtained from A and B, respectively, by reducing the probability of gain by a factor of 4. Hence, C is expressible as a compound prospect $(A, 1/4, 0)$, whereas D is expressible as $(B, 1/4, 0)$. The substitution axiom of utility theory asserts that if A is preferred to B, then the (probability) mixture $(A, p, 0)$ must be preferred to the mixture $(B, p, 0)$.

Our subjects did not obey this axiom. Apparently, reducing the probability of winning from 1.0 to 0.25 has a greater effect than the reduction from 0.8 to 0.2. More generally, it appears that if a risky prospect $(x, p, 0)$ is equivalent to a sure prospect (y) then $(x, pq, 0)$ is preferred to $(y, q, 0)$, contrary to the substitution axiom.

The certainty effect was first demonstrated by Allais (1953) and further investigated by many authors from both normative and descriptive standpoints, see

MacCrimmon and Larsson (1976). It was found that respondents, presented with Allais' problems, typically violate expected utility theory. Moreover, many of these respondents do not change their decisions even when they are shown that their preferences are incompatible with the axioms of the theory [see, for example, Slovic and Tversky (1975)]. Allais' examples involve very large sums of money and small probabilities although neither of these features is essential.

The certainty effect is not the only source of violation of the expectation principle. Another context in which substitution fails is illustrated by the following problems.

$$A = (1000, 0.90, 0) \quad \text{vs.} \quad (2000, 0.45, 0) = B$$

$$C = (1000, 0.002, 0) \quad \text{vs.} \quad (2000, 0.001, 0) = D$$

As in Set 2, C and D are obtained from A and B, respectively, by reducing the probability of winning by the same factor. Unlike Set 2, however, both A and B are risky prospects, and the reduction factor is large so that the reduced probabilities of winning are small. The majority of subjects who were presented with the above choices selected A in the first problem and D in the second, contrary to the substitution axiom.

Note that in the first problem the probabilities of winning are substantial (.90 and .45), and most people chose the prospect where winning is more probable (A). In the second problem, there is a possibility of winning, although the probabilities of winning are minuscule (.002 and .001)

in both prospects. In this situation, where winning is possible but not probable, most people chose the prospect that offers the larger gain (D). This type of violation of expected utility theory, arising from large reductions in the probabilities of winning, is called the possibility effect. It is as if very small probabilities are treated similarly -- as possibilities -- without proper appreciation of their actual values.

The certainty effect and the possibility effect reflect common attitudes toward risk or chance that cannot be captured by any utility function within the expected utility framework. They can both be described in terms of the following condition:

If $(x, p, 0)$ is equivalent to $(y, pq, 0)$, then $(y, pqr, 0)$ is preferred to $(x, pq, 0)$, provided $0 \leq p, q, r \leq 1$. The case $p = 1$ corresponds to the certainty effect, and the possibility effect corresponds to the case where r is very small. Under expected utility theory, of course, the equivalence of $(x, p, 0)$ and $(y, pq, 0)$ implies the equivalence of $(x, pr, 0)$ and $(y, pqr, 0)$.

1.2 The Reflection Effect

The previous section discussed preferences between non-negative prospects, that is, prospects that involve no losses. What happens when the signs of the outcomes are reversed so that gains are replaced by losses? The left part of Table 1-1 summarizes the preferences between the non-negative prospects discussed in the previous section,

and the right part of Table 1-1 describes the preferences between the respective non-positive prospects obtained by changing gains into losses. Table 1-1 displays the modal preferences, that is, the choices made by the majority of subjects. We use $-x$ to denote the loss of x , and $>$ to denote the relation of preference between prospects.

Inspection of Table 1-1 reveals that the pattern of preferences between the non-positive prospects is the mirror image of that between the non-negative prospects. Thus, the reflection of these prospects around zero reverses the preference order. This phenomenon is called the reflection effect. This effect has several important implications. First, it extends the certainty effect (Sets 1 and 2) and the possibility effect (Set 3) to the negative domain. Thus, it provides further evidence against expected utility theory.

Second, it demonstrates the presence of risk-prone choices between non-positive prospects. For example, the great majority of our subjects would rather take the gamble $(-1000, 0.80, 0)$ than accept a sure loss of 750, although the gamble has a lower expected value. These observations violate risk-aversion and suggest that the certainty equivalent of a non-positive prospect is often greater than its expected actuarial value. Thus, risk-aversion cannot be accepted as a general descriptive principle of decision under risk.

Third, the reflection effect imposes considerable constraints on the theoretical interpretation of the failures of expected utility theory. The certainty effect

TABLE 1-1

MODAL PREFERENCES BETWEEN NON-NEGATIVE
AND NON-POSITIVE PROSPECTS

<u>Set</u>	<u>Non-negative Prospects</u>	<u>Non-positive Prospects</u>
1	(750) > (850, 0.95, 0)	(-750) < (-850, 0.95, 0)
	(750, 0.55, 0) < (850, 0.50, 0)	(-750, 0.55, 0) > (-850, 0.50, 0)
2	(750) > (1000, 0.80, 0)	(-750) < (-1000, 0.80, 0)
	(750, 0.25, 0) < (1000, 0.20, 0)	(-750, 0.25, 0) > (-1000, 0.20, 0)
3	(1000, 0.90, 0) > (2000, 0.45, 0)	(-1000, 0.90, 0) < (-2000, 0.45, 0)
	(1000, 0.002, 0) < (2000, 0.001, 0)	(-1000, 0.002, 0) > (-2000, 0.001, 0)

in the positive domain could have been attributed to the regret induced by the comparison of risky and riskless prospects, to an aversion for gambling, or to the variance of the utility of outcomes. All these accounts, however, are incompatible with the presence of the certainty effect in the negative domain.

1.3 The Reference Effect

According to expected utility theory, the carriers of utility are asset positions that include one's wealth as well as the outcomes of the prospect under consideration. Thus, the prospect (x, p, y) is preferred to (z) in asset position w if and only if

$$U(w+x, p, w+y) = pu(w+x) + (1-p)u(w+y) > u(w+z).$$

In contrast, people usually do not properly combine the possible outcomes of the prospect with their current asset position. Instead, they regard the status quo as a reference point, and evaluate the outcomes as positive or negative changes, that is, as gains or losses. Hence, two choices that are identical in terms of (final) asset positions but differ in reference points often produce different responses. This behavior, called the reference effect, is illustrated by the following problems.

Problem I. In addition to whatever you own, you have been given 1000. You are now asked to choose between:
A = (500) vs. B = (1000, 1/2, 0)

Problem II. In addition to whatever you own, you have been given 2000. You are now asked to choose between:
 $C = (-500)$ vs. $D = (-1000, 1/2, 0)$

The majority of subjects chose A in the first problem and D in the second. These preferences are inconsistent with utility theory, because, in terms of final assets:

$$A = (w + 1500) = C \text{ and } B = (w + 2000, 1/2, w + 1000) = D$$

where w denotes the subject's initial wealth. In fact, Problem II is obtained from Problem I by adding 1000 to the initial bonus and subtracting 1000 from all outcomes. Hence, if A is preferred to B, then C should be preferred to D.

Evidently, the subjects did not integrate the bonus with the prospects. Since the same bonus (1000 or 2000) was added to both prospects in each problem, it was apparently treated as a (small) change in wealth, which has little or no effect on the choice between prospects. Thus, Problem I was viewed as a choice between non-negative prospects, whereas Problem II was viewed as a choice between non-positive prospects, although the two problems are actually identical. As noted earlier, people tend to be risk-averse in the former context and risk-prone in the latter.

In contrast to the marked effect produced by shifting 1000 from the bonus to the prospects, a change of 1000 in the bonus alone has little or no effect on the preference order. Subjects presented with a modified version of Problems I and II, in which the bonuses of 1000 and 2000 were interchanged, exhibited the same pattern of preference that was observed

in the original problems. Thus, people appear to be relatively insensitive to small (or even moderate) changes in assets, and highly sensitive to reformulations of prospects that change the sign of outcomes. These observations show that people fail to properly integrate prospects with assets; they also suggest that the effective carriers of utility are (positive or negative) changes from one's reference point, rather than final asset positions.

The preceding sections indicate that people's attitudes toward change and risk cannot be captured by expected utility theory. The next sections develop an alternative theory of decision making under risk, called prospect theory. This theory preserves the general (bilinear) structure of expected utility theory, but it replaces some of its basic tenets to provide a better account of choice behavior under uncertainty. Like any general formal theory of choice, the present theory does not encompass all the complexities involved in specific decision problems. Rather, it attempts to abstract the key variables and to describe the manner in which they interact.

2. PROSPECT THEORY

Prospects of the form (x,p,y) can be classified according to the signs of their outcomes. A prospect is mixed if one outcome is positive and the other outcome is negative. It is semi-positive or semi-negative, respectively, if one outcome is zero and the other is positive or negative. It is strictly positive or negative, respectively, if the outcomes are either both positive or both negative.

The certainty equivalent of the prospect (x,p,y) is the amount $C(x,p,y)$ for which one is indifferent between playing the gamble (x,p,y) and receiving or paying $C(x,p,y)$ for sure. The present theory is formulated in terms of two basic equations. The first equation applies to purely positive and purely negative prospects. These prospects can be decomposed into two components. (i) The riskless component, that is, the minimum gain or loss which is certain to be obtained or paid. (ii) The risky component, that is, the additional gain or loss which is actually at stake. Equation (1) describes the manner in which the riskless and risky components are combined to determine the certainty equivalent of the prospect.

(1) Translation: If $x>y>0$ or $x<y<0$, then $C(x,p,y) = y+C(x-y,p,0)$.

Thus, the certainty equivalent of a strictly positive (negative) prospect is the riskless component y , plus the certainty equivalent of the residual semi-positive (semi-negative) gamble, $C(x-y,p,0)$. For example,

$$C(400, 1/2, 100) = 100 + C(300, 1/2, 0),$$

and

$$C(-500, 1/10, -200) = -200 + C(-300, 1/10, 0).$$

As in expected utility theory, the present theory associates a value V with each prospect so that the preference ordering between them coincides with the ordering of their v -values. That is, prospect A is preferred to prospect B if and only if $V(A) > V(B)$. The overall value of a prospect is expressed in terms of two scales: v and π . The former assigns to each outcome x a number $v(x)$ that reflects the value of that outcome. The latter associates with each probability p an uncertainty weight $\pi(p)$ which reflects the contribution of p to the overall value of the prospect. The second equation of the theory describes the relation between these scales.

(2) Weighting: If $x > 0 > y$ or $x < 0 < y$, then

$$V(x, p, y) = \pi(p)v(x) + \pi(1-p)v(y),$$

where $v(0) = 0$.

Recall that V is defined on prospects, while v is defined on outcomes. The two scales coincide for degenerate gambles where

$$V(x, p, x) = V(x) = v(x)$$

Equation (2) is analogous to the expected utility formulation except that the classical utilities and probabilities are replaced by values and uncertainty weights, respectively. The significance of the difference lies in that π is not a probability measure. In particular, $\pi(p)$ and

$\pi(1-p)$ need not sum to one. Furthermore, v measures the value of changes (gains and losses) from a given asset position rather than the combined value of assets plus outcomes. In principle, therefore, one has a collection of value functions, one for each asset position. As we already observed, however, the preference order between prospects is not very sensitive to small or moderate changes in assets. Moreover, it is argued below that the major qualitative properties of the value function are essentially independent of asset position. Consequently, much of the present analysis can be carried out without precise specification of asset position.

Combining Equations (1) and (2) yields

$$(3) \quad V(x, p, y) = v(z) + \pi(p)v(x-z) + \pi(1-p)v(y-z)$$

$$\text{where } z = \begin{cases} \min(x, y) & \text{if } x, y > 0 \\ \max(x, y) & \text{if } x, y < 0 \\ 0 & \text{otherwise} \end{cases}$$

The properties of the value function and the uncertainty weights will be discussed in the following sections.

It should be noted that although the above formulation is new, some of its components were discussed by previous authors. In particular, the present translation condition (1) follows from a stronger translation property investigated by Pfanzagel (1959). The bilinear utility model (where probabilities do not add to one) was introduced by Edwards (1962), and studied by Tversky (1967) and Shanteau (1975).

Finally, the role of the reference point on the utility scale was discussed by Markowitz (1952), Edwards (1954) and Hansson (1975).

2.1 The Value Function

The present section discusses several hypotheses concerning human judgment which determine qualitative properties of the proposed value function.

(i) The reference hypothesis: The domain of the value function consists of (positive or negative) changes in wealth, that is, gains and losses. This hypothesis is required to explain the reference effect. It is also compatible with some basic principles of perception and judgment. Our perceptual apparatus is attuned to the evaluation of changes or differences rather than to the evaluation of absolute magnitudes. People are much better at detecting changes in illumination or noise level, than at evaluating the absolute levels of these attributes. The past and present context of experience generally defines an adaptation level, or a reference point, and stimuli are perceived in relation to an adaptation level (Helson, 1964). For example, an object at a given temperature may be experienced as hot or cold to the touch, depending on the temperature of objects to which one has adapted.

(ii) The steepness hypothesis: The value function becomes steeper as one approaches the reference point from either above or below. It has been traditionally assumed that utility is a concave function of money, or equivalently, that the marginal utility of money decreases with wealth.

In contrast, we hypothesize that the value function is concave above the reference point and convex below it; that is, the marginal utility of money decreases with the distance from the reference point.

The steepness of the value function at a given point can be interpreted as the local sensitivity to changes. Under this interpretation, the steepness hypothesis implies that one is maximally sensitive to changes near his reference point, and that sensitivity decreases as one moves away from the reference point in either direction. This principle applies to many sensory and perceptual attributes, and it is highly adaptive. It maximizes the sensitivity of the perceptual system to small changes that are most commonly encountered.

(iii) The gain-loss hypothesis: The value of negative changes is greater (in absolute value) than the value of positive changes, that is, losses loom larger than gains. Thus, most people avoid symmetric bets of the form $(x, 1/2, -x)$, presumably because the disutility of losing x exceeds the utility of gaining x . Moreover, the prevalent preference order between such gambles is inversely related to the magnitude of x . Hence, if $x > y$ then, by Equation (2)

$$\pi(1/2)[v(x) + v(-x)] < \pi(1/2)[v(y) + v(-y)]$$

hence

$$v(x) - v(y) < v(-y) - v(-x).$$

Consequently, $v(x) < -v(-x)$, and $v'(x) < v'(-x)$ for all x , provided the first derivative of v exists. That is, the

value function for losses is steeper than the value function for gains.

The greater sensitivity to negative rather than positive changes is not specific to monetary outcomes. It reflects a general property of the human organism as a pleasure machine. For most people, the happiness involved in receiving a desirable object is smaller than the unhappiness involved in losing the same object. A high sensitivity to losses, pains, and noxious stimuli also has adaptive value. Happy species endowed with infinite appreciation of pleasures and low sensitivity to pain would probably not survive the evolutionary battle.

The proposed value function has three essential features. First, it is defined for gains and losses rather than for wealth (the reference hypothesis). Second, it becomes steeper as one approaches the origin from either above or below (the steepness hypothesis). Third, it is steeper for negative changes than for comparable positive changes (the gain-loss hypothesis). An example of value function for money with the above features is displayed in Figure 2-1.

2.2 Uncertainty Weights

In prospect theory, as in utility theory, the value of each possible outcome of a gamble is weighted by some function of the probability of occurrence of that outcome. However, prospect theory distinguishes between the subjective probability of the outcomes and the weight that these outcomes are assigned in computing the over-all value of a gamble. The latter are called uncertainty weights.

Subjective Value of Change -- $v(x)$

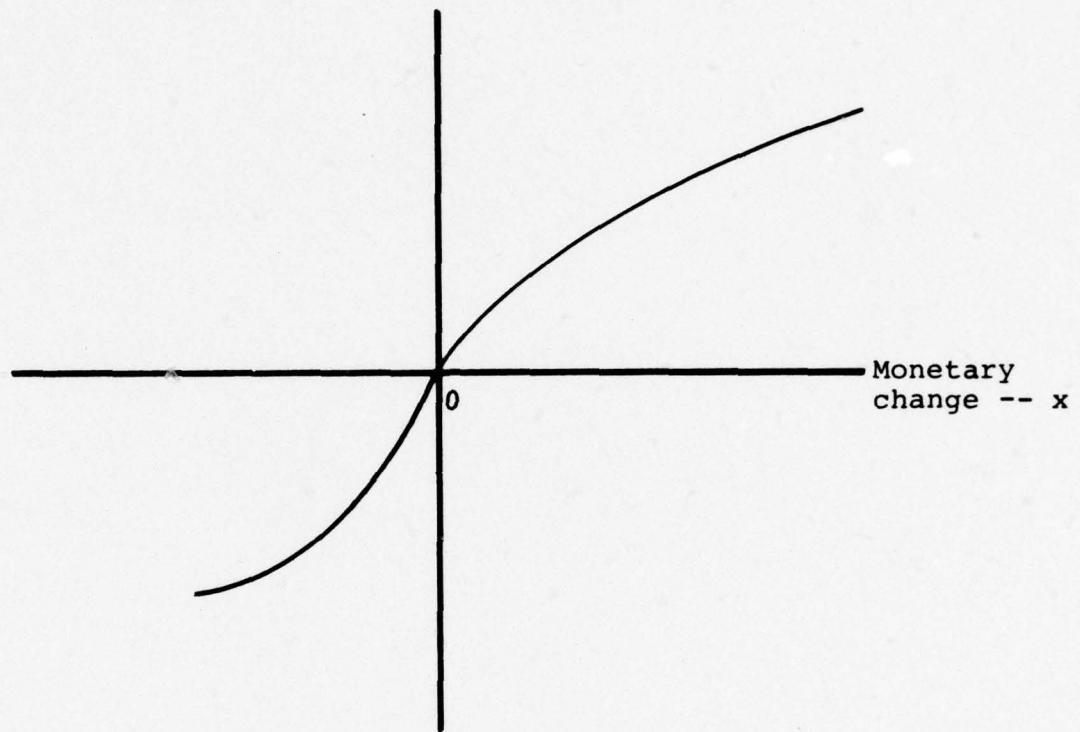


FIGURE 2-1. ILLUSTRATIVE VALUE FUNCTION

An uncertainty weight is not a subjective probability: it does not measure a person's degree of belief in the likelihood of an event. Consider a gamble in which one can win 1000 or nothing, depending on the toss of a fair coin. In this situation, the probability of winning is 1/2 for any reasonable person. This could be verified in a variety of ways, for example, by showing that the subject is indifferent between betting on heads or tails, or by his verbal report that he considers the two events equiprobable. However, the uncertainty weight, $\pi(1/2)$, derived from the subject's choices, may differ from 1/2. The uncertainty weight reflects a person's readiness to gamble on an event, rather than his degree of belief in its occurrence. These measures coincide if the expectation principle holds, but not otherwise.

The uncertainty weight associated with an event is a function of one's subjective probability for that event. In the problems analyzed in the present paper, we assume that the subject adopts the stated values as his subjective probabilities, and we may therefore express the uncertainty weights as a function of stated probabilities. We turn now to discuss the properties of uncertainty weights. Naturally, π is assumed to be a strictly increasing function of p , with $\pi(0) = 0$ and $\pi(1) = 1$.

Recall that both the certainty and the possibility effect are expressible by the following condition. If $(x,p,0)$ is equivalent to $(y,pq,0)$, then $(x,pr,0)$ is not preferred to $(y,pqr,0)$, $0 \leq p,q,r \leq 1$. The certainty effect corresponds to the case $p = 1$, while the possibility effect

corresponds to the case where r is quite small. Applying Equation (2) to the following condition yields:

$$\pi(p)v(x) = \pi(pq)v(y) \text{ implies } \pi(pr)v(x) \leq \pi(pqr)v(y),$$

$$\text{hence, } \frac{\pi(pq)}{\pi(p)} = \frac{v(x)}{v(y)} \leq \frac{\pi(pqr)}{\pi(pr)},$$

$$\text{and } \pi(pq)\pi(pr) \leq \pi(pqr)\pi(p).$$

Let $\bar{\pi}(p) = \log \pi(p)$, and $\bar{p} = \log p$. Hence, the above inequality holds if and only if

$$\bar{\pi}(\bar{p} + \bar{q}) + \bar{\pi}(\bar{p} + \bar{r}) \leq \bar{\pi}(\bar{p} + \bar{q} + \bar{r}) + \bar{\pi}(\bar{p}),$$

which holds if and only if $\bar{\pi} = \log \pi$ is a convex function of $\bar{p} = \log p$. Note that the certainty effect alone implies that $\bar{\pi}$ is a superadditive function of \bar{p} , that is,

$$\bar{\pi}(\bar{q}) + \bar{\pi}(\bar{r}) \leq \bar{\pi}(\bar{q} + \bar{r}).$$

If certainty (rather than impossibility, or even odds) is the natural reference point for the assessment of uncertainty weights, then the implied property, called logarithmic convexity, may be viewed as a manifestation of the general steepness hypothesis according to which subjective scales become steeper as one moves toward the reference point. Note that logarithmic convexity does not imply regular convexity: if $\log \pi$ is convex in $\log p$, π is not necessarily convex in p . An illustrative example of an uncertainty function satisfying logarithmic convexity is displayed in Figure 2-2.

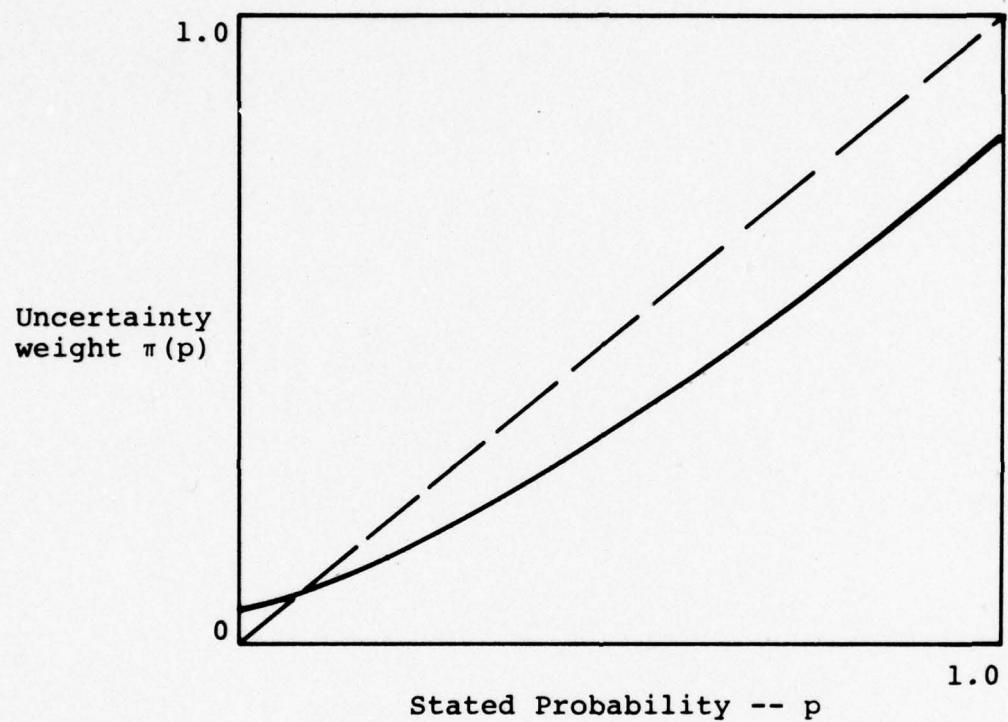


FIGURE 2-2. ILLUSTRATIVE UNCERTAINTY FUNCTION

Note that, in Figure 2-2, π has abrupt drops or discontinuities at its endpoints, which reflect the anomalous responses to extreme probabilities. On some occasions people appear to ignore events (e.g., a car accident or a natural disaster) with small probabilities and behave as if these events will not occur. On other occasions, people overweigh events with very small probabilities, and underweigh their complements. It seems as if events that do not pass some low threshold are viewed as practically certain. However, if a low probability event passes the threshold and is recognized as a possibility, it is often overweighted. In the same manner, a high probability event that is recognized as uncertain is typically underweighted. The conditions under which events are discarded, underweighted, or overweighted, are probably affected by the manner in which they are represented or displayed (Kahneman and Tversky, 1974).

The present treatment is not restricted to stated probabilities that are accepted by the subject. In the absence of such probabilities, we assume that the subject establishes his own probabilities and applies the π -function to them. This discussion has distinguished subjective probability, which is a measure of degree of belief, from the uncertainty weight that is inferred from gambling decisions. Our analysis suggests that attempts to infer subjective probabilities from risky choices actually recover uncertainty weights, which reflect attitudes to risk as well as degree of belief.

3. IMPLICATIONS

It is easy to verify that the proposed theory accounts for the major violations of expected utility theory demonstrated earlier in this paper. In particular, the certainty and the possibility effects, in both the positive and the negative domains, follow from the logarithmic convexity of the uncertainty function. The change from risk aversion to risk seeking, which occurs when prospects are reflected around zero, follows from the S-shaped form of the value function which also implies the reference effect. It is also easy to show that Allais' (1953) examples can be explained in the same manner. The following sections discuss some of the broader implications of prospect theory in comparison to expected utility theory.

3.1 Insurance and Gambling

People spend billions of dollars to purchase insurance policies and lottery tickets, despite the negative expected values of both forms of investment. These behaviors present a major challenge to any descriptive theory of choice under risk. The best-known explanations of insurance and gambling refer to the shape of the utility function for money. The common assumption that utility is a concave function of wealth explains the risk-averse purchase of insurance, but it fails to explain the risk-seeking purchase of lottery tickets. To explain both behaviors, Friedman and Savage (1948) had to invoke a utility function that is concave in some regions and convex in others.

The value function introduced in the present theory explains neither insurance nor gambling. Since it is concave above zero and convex below zero, it favors risk-aversion in the domain of gains and risk-seeking in the domain of losses, and tends to make both insurance and gambling unattractive. In this theory, insurance and gambling occur in spite of the value function, not because of it. They are explained in prospect theory by the properties of the uncertainty weights.

The common feature of lotteries and insurance is that they involve a small probability of a large gain or loss. Overweighting this probability increases the attractiveness of a lottery and the aversiveness of an uninsured risk. Because $\pi(p) > p$ for small probabilities, people may be willing to pay more than the expected value of lottery tickets and insurance policies, although the shape of the value function militates against such choices.

The evidence suggests that risky choices cannot be adequately explained by a utility function for money. It is necessary, in addition, to consider attitudes toward uncertainty that are expressed in the overweighting of unlikely outcomes and in the underweighting of outcomes which are probable but not certain. When the probabilities of gain or loss are substantial, the uncertainty weights, in conjunction with the properties of the value function, produce risk-seeking in the negative domain and risk-aversion in the positive domain. When the probabilities are small, the uncertainty weights can produce risk-aversion in the negative domain (e.g., insurance) and risk-seeking in the positive domain (e.g., gambling).

The present theory does not purport to account for all forms of risk-seeking and risk-aversion. Many factors not included in this theory (e.g., regret, social pressure, superstition, magical thinking) probably play an important role in risky choices. Prospect theory is an attempt to modify those assumptions of utility theory that are most severely violated, so as to achieve a more realistic account of choice behavior.

3.2 Alternative Formulations of Choice Problems

Earlier in this paper we showed that two formulations of a choice problem which differ in gains and losses may lead to different preferences, although the two formulations are identical in terms of final assets. What constitutes a gain or a loss, however, depends on the representation of the problem and on the context in which it arises. Consider, for example, a man who has spent an unhappy afternoon at the horse races, has already lost \$100 on the first four races and is now facing a decision on how to place his bet on the fifth and last race of the day. Being aware that he is \$100 out of pocket, he is likely to regard the decision of whether to pay \$10 on a 15:1 longshot as a choice between $(40, p, -110)$ and (-100) , rather than as a choice between $(140, p, -10)$ and (0) . It follows from the present theory that a person is more likely to choose the gamble in the former representation than in the latter. This prediction is confirmed by the well-known observation that betting on longshots increases in the course of the racing day.

There are many other contexts in which the decision-maker evaluates a gamble in terms of gains and losses that differ from the actual sums of money that will change hands. We propose that the present theory applies to the gains and losses as perceived by the subject. A businessman who is doing less well than his competitors may view the maintenance of the status quo as a loss, although his balance shows a profit. Conversely, an entrepreneur who is weathering a slump with greater success than his competitors may interpret a small loss as a gain, relative to the larger loss that he had reason to expect. The tourist who had budgeted \$50 for spending in a Las Vegas casino may regard all available bets as semi-positive, because he feels that the costs have already been paid in advance. These examples involve transformations which modify the perception of the gains and losses associated with the various options.

We have argued that subjects tend to evaluate risky options in terms of gains and losses. However, people surely can and sometimes will evaluate options in terms of final consequences, as advocated by utility theory. In this case, all gambles will be viewed as positive, and the effective value function will be concave everywhere. Consider, for example, an individual whose current wealth is \$60,000, and who is faced with a choice between $(-1000, 1/2, 0)$ and (-500) . Our results suggest that this individual would make a risk-seeking choice and prefer the gamble over the sure loss. However, this preference is quite likely to be reversed if a decision analyst suggests to the individual that he should formulate the alternatives as $(59,000, 1/2, 60,000)$ vs. $(59,500)$. Here, a risk-averse choice appears more likely. Indeed, the individual's experience of the consequences of

his choice may be affected by his formulation of the problem. It is conceivable, for example, that the decision-maker may face a sure loss of \$500 with greater fortitude if he views the problem in terms of final assets rather than in terms of gain and loss.

The casting of choice problems in terms of final consequences eliminates one major class of risk-seeking choices that are due either to the certainty effect or to the convexity of the value function in the negative domain. On the other hand, this formulation does not eliminate a second class of risk-seeking preferences which reflect the overweighting of small probabilities, namely, the purchase of lottery tickets.

3.3 Normative Implications

Utility theory has been used in two ways: as a descriptive theory of human choices under uncertainty, and as a prescriptive theory of how a rational person should behave. The main conclusion of the present paper is that utility theory does not provide an adequate description of the choices people make between risky options. We turn now to examine the prescriptive implications of this conclusion.

The great majority of decision theorists regard the axioms of utility theory as valid normative principles of decision making under uncertainty. They believe that any reasonable person who understands the axioms would wish to satisfy them and would regard their violation as an error. The knowledge that strict adherence to the axioms will

protect one from losing propositions (e.g., a Dutch book) increases the normative appeal of the theory. The idea that people wish to obey utility theory, even though they often violate it in practice, is the basis of many prescriptive applications. In decision analysis, for example, the relevant utilities and subjective probabilities of the decision-maker are inferred from his responses to hypothetical choice problems, and these values are then used to select the prospect whose expected utility is maximal.

To justify this prescriptive application of utility theory, one assumes first that the theory is adequate from a normative standpoint, and second that the observed departures from the theory represent error, confusion, and other aberrations. If the violations of the axioms are large and systematic rather than small and random, it is impossible to infer utilities and probabilities from reported preferences. The application of decision analysis therefore depends on the descriptive validity of utility theory, at least as a first approximation.

We have argued that the observed violations of utility theory are both large and lawful, and that they cannot be treated as random error. Specifically, two sources of violations of expected utility theory have been identified. The first is the tendency to isolate a choice problem from one's assets and evaluate it in terms of gains and losses. The second is the replacement of subjective possibilities by uncertainty weights which reflect attitude to uncertainty and not merely degree of belief. These findings invalidate the attempt to infer utilities and subjective probabilities

from preferences. No consistent utility function for wealth can be inferred from the choices of a subject who evaluates gains and losses according to an S-shaped value function. Similarly, one cannot recover a proper subjective probability measure from the preferences of a subject who applies uncertainty weights. The observation that people's preferences vary with the formulation of problems underscores the need for decision aids to help people make more consistent and rational choices. At the same time, these observations put into question the adequacy of the procedures used in decision analysis to elicit utilities and probabilities [see, for example, Raiffa (1961)].

There is a discrepancy between the manner in which the consequences of risky choices are actually perceived and experienced and the manner in which they are commonly interpreted in utility theory. People naturally think of consequences as changes, whereas utility theory formulates consequences as states of wealth. If man is constructed in such a way that he is much more sensitive to gains and losses than to absolute wealth, then any attempt to maximize human welfare must recognize this fact. More generally, a normative approach to decision making must take into account the nature of man as a pleasure machine. If rational behavior is that which maximizes likely pleasure and minimizes likely pain, then the laws of these experiences should be an essential part of any normative theory of choice.

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4. TITLE (and Subtitle) PROSPECT THEORY: AN ANALYSIS OF DECISION MAKING UNDER RISK		5. TYPE OF REPORT & PERIOD COVERED Technical Report
7. AUTHOR(s) Daniel Kahneman Amos Tversky		6. PERFORMING ORG. REPORT NUMBER (15) N00014-76-C-0074
9. PERFORMING ORGANIZATION NAME AND ADDRESS Decision Research A Branch of Perceptronics 1201 Oak Street, Eugene, Oregon 97401		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ARPA Order 3052
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency 1400 Wilson Blvd. Arlington, Virginia 22217		12. REPORT DATE Apr 1977
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Office of Naval Research, Code 455 800 No. Quincy Street Arlington, Virginia 22217		13. NUMBER OF PAGES 47
16. DISTRIBUTION STATEMENT (of this Report) Approved for Public Release; Distribution Unlimited		15. SECURITY CLASS. (of this report) Unclassified
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES None		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Utility Theory Decision Analysis Decision Making Risk Uncertainty Subjective Probabilities		
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